

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
13 November 2003 (13.11.2003)

PCT

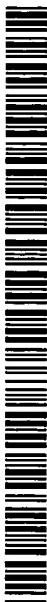
(10) International Publication Number  
**WO 03/093696 A2**

- (51) International Patent Classification<sup>7</sup>: **F16F**
- (21) International Application Number: PCT/NO03/00124
- (22) International Filing Date: 14 April 2003 (14.04.2003)
- (25) Filing Language: Norwegian
- (26) Publication Language: English
- (30) Priority Data:  
20022077 30 April 2002 (30.04.2002) NO
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- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



**WO 03/093696 A2**

(54) Title: DAMPING APPARATUS FOR THE DAMPING OF VIBRATIONS

(57) Abstract: The present invention concerns a damping apparatus for the damping of vibrations in tool holders, machine elements and work pieces in machine tools and in other objects that are exposed to unwanted vibrations. The damping apparatus is adapted to be provided in or on the object and includes a substantially cylindrically shaped damping body (1) with a boring (6) going through and a through the boring extending longitudinal central body (3) that is rigidly connectable to the object that is to be damped. The damping body (1) is connected to the longitudinal central body through elastic elements (2). The connection is made such that the elastic elements (2) are substantially exposed to shear forces during damping.

**Damping apparatus for the damping of vibrations.**

The present invention concerns a damping apparatus that particularly but  
5 not exclusively is designed for boring bars and similar tool holding bars used in  
machine tools. Typical examples are boring bars used for chip cutting machining  
(turning, milling, etc.) on weak constructions, such as shafts and similar ele-  
ments. The apparatus may also be used on "clampings", other parts of a ma-  
chine, and works pieces. Self generating oscillations are typically a result of the  
10 dynamic rigidity of a construction being too small.

Similar damping apparatuses are previously known, and a related appara-  
tus is shown in NO patent 128 725. This patent concerns a damping device that  
necessarily must be placed in a boring in the boring bar, because the boring itself  
constitutes an important part of the damping device, in that the damping effect is  
15 a result of an interaction between the damping body and the boring itself, through  
resilient elements provided between the damping body and the boring.

The development evolves towards an increased ration between  
length/diameter (overhang) on tool holders. This results in a reduction of the dy-  
namic rigidity of the tool holder and this again impose new requirements to the  
20 damping device that must be adapted accordingly. The problem with the damp-  
ing device according to the known art is that to adapt the damping device to  
these new conditions, the frequency of the damping body must be lowered. To  
achieve this, either resilient elements with a lower spring constant, or a damping  
body with a larger mass is required.

25 The density of the damping bodies used to day is already among the high-  
est commercially available. To increase the mass, the volume of the damping  
body must therefore be increased. This will result in problems related to space  
and size and weakening of the construction where the damping apparatus is to  
be placed.

30 To be able to reduce the spring constant with solutions according to the  
known art, as for instance described in NO patent 172 677, must accordingly ei-  
ther the material in the resilient element be changed to a softer material with a  
lower spring constant, or the strength of the resilient element must be reduced by  
reducing the size of the element. At the same time, the resilient elements must

resist heat that is developed during the chip cutting process, and as a result of energy absorption in the material, in addition to being dimensioned to withstand forces they are exposed to. This has proved to be contradicting properties.

The conclusion is that the solutions according to the known art therefore  
5 not is well suited in the development towards an increased length/diameter ratio and a lower natural frequency for a system that is to be damped, due to limitations in material properties amongst other things.

High rotational speeds are often used, and it is therefore also important  
10 that a damping system can withstand fast rotation. This has also proved problematic with apparatuses according to the known art.

The present invention solves the abovementioned problems by providing a new damping apparatus. The damping apparatus according to the invention is suited to dampen self generated vibrations in boring bars, tool holding bars and the like, preferably rotating machine elements, in particular elements with internal  
15 fluid cooling, and the damping apparatus comprises a substantially cylindrically shaped damping body.

The solution is based on a technology where the forces are transferred from the bar to the damping body through resilient elements, where the resilient elements substantially are exposed to shear forces, as opposed to the known art  
20 where corresponding resilient elements mainly are exposed to pressure forces. The advantage of transferring the forces as shear forces instead of pressure forces, is that the spring constant can be lowered and the dampening properties of the material increases when transferring the forces in the shear direction as opposed to transferring the forces in compression.

25 The G-module, that expresses the stiffness of elastomers exposed to shear forces, is considerably lower than Ec, which expresses the stiffness to elastomers exposed to pressure, and approximately 1/3 of Es that expresses the stiffness of elastomers exposed to tension. In a damping apparatus where the elastic elements/resilient elements (the elastomers) substantially are exposed to shear forces, the spring constant of the system will potentially be reduced, and it  
30 is thereby possible to reduce the natural frequency of the damping apparatus considerably without changing the material composition of the elastic element, and without reducing the size or strength of the element. The mass of the damping body does not need to be increased either. Another advantage is increased

bandwidth of the damping function, and that the size of the elastic element that for instance is made of rubber, can be increased and thereby result in increased damping, without increasing the natural frequency in relation to existing solutions of the same size. Thereby the damping apparatus can allow for greater variation  
5 in the ratio between length and diameter. One advantage of this is the possibility to eliminate damping fluid as a damping medium because increased amount of rubber or other elastic materials is sufficient as the only energy absorbent in the system.

One advantage with the ability to lower the frequency is that the mass of  
10 the damping body may be reduced while achieving the same natural frequency as existing systems. This makes the invention more useful in applications where the damping system is to rotate with a high velocity, with considerable centrifugal forces, such as in high velocity milling applications.

The fact that the mass of the damping body may be reduced is useful in  
15 that the diameter of a central tube, that may transport cutting fluid to the cutting edge, may be increased. The amount of cutting fluid that can be brought forward can with this solution thereby be increased as compared to present solutions. The advantage with an increased amount of cutting fluid is a more effective removal of chips from the cutting edge.

Another known problem with the solution described in NO patent 172 677,  
20 is that the damping fluid in the cavity between the mass and the central tube, can leak past the elastomer used as a resilient element, if this is utilized as a dynamical seal and not is bound to the surrounding parts.

The solution as suggested in the present invention eliminates this problem  
25 as the resilient elastomer is directly bound to the surrounding structure, or if alternatively static seals are used.

The damping body of the damping apparatus has an axial boring going there through. The resilient elements, or the elastic elements are provided in each end of the damping element and are connected to a, through the boring  
30 axially extending longitudinal central body or tube.

In one application, the apparatus may be provided in a thereto adapted cavity with a substantially axial and cylindrical shape inside a boring bar. The tube may be rigidly connectable to an internal boring for cooling fluid in the boring

bar (as the resilient or elastic elastic elements are held in place by means of externally provided washers).

In one embodiment, the present invention allows for supply of cooling fluid to a cutting edge in that the cooling fluid is led straight through the axial area of the damping apparatus when the longitudinal central body is shapes as a tube. This construction allows that the same cavity in the boring bar may include a damping body. The gap between the damping body and the wall of the cavity may be reduced considerably, such that the diameter of the damping body can be increased.

In one embodiment, the outer diameter of the axially extending longitudinal central body is adapted to the diameter of the boring with a small gap for accepting a damping medium, for example a damping fluid such as damping oil.

In one embodiment, the gap for the damping medium may be placed close to the axis of the damping body and the boring bar to reduce the effect of the centrifugal force on the medium to an acceptable level, which has a favourable effect when the damping system must rotate at high speed.

The damping apparatus will now be described with reference to embodiments, and to the enclosed drawings, where

Fig. 1 shows the damping apparatus in its most simple and basic embodiment,

Fig. 2 shows the damping apparatus in a embodiment, where the assembly and installation has been considered,

Fig. 3 shows a damper according to the known art build into a boring bar, and

Fig. 4 shows a way of installing of the damping apparatus when this is to be placed on a plane object to be damped.

Figure 1 shows an example of a simple design of a damping apparatus according to the invention. The substantially cylindrical damping body 1 is provided with an axial boring 6 going there trough. Inside the boring, there is an axially extending longitudinal central body or tube 3 that generally is adapted to be rigidly secured at its outer ends inside a boring bar or to the object that is to be damped. The tube 3 is preferably adapted to lead a cooling fluid through itself in communication with a channel extending further into the boring bar. In each outer end of the damping body 1, it is connected elastic elements 2 with a circu-

lar shape with for instance a rectangular cross section. The elastic elements 2 can thereby be shaped as elastic washers or short hollow cylinders, with an opening for the passage for the longitudinal central body 3 going there trough and two opposite facing end faces. The end faces will normally be substantially parallel. The elastic elements 2 may for instance be made of rubber or another elastic material. The longitudinal central body 3 is rigidly connected with one of the end faces, and the damping body 1 is rigidly connected with the other end face in that the elastic elements 2 furthermore is connected to washers or end pieces 5 that again is connected to the tube 3 by for instance vulcanization or adhesive bonding. The washers 5 are preferably secured to the tube 3 with a screw connection, but do not necessarily be so. The natural frequency of the system is varied by changing the dimensions or the material properties of the elastic element 2.

Figure 2 shows an example where the assembly of the various parts is considered. In this example the elastic elements 2, are connected to intermediate washers 7 on each side.

The connection may be made during the moulding of the elastic elements 2 and is made by applying adhesives on the contact faces of the intermediate washers 7. The intermediate washers 7 facilitate the assembly of the elastic elements 2 to the damping body 1 and the washers 5. The intermediate washers 7 can for instance be secured to these parts with adhesives, and seal against leakage of oil. Alternatively they may be secured with mechanical locking, and with sealing rings 8 in the contact faces to prevent leakage, as shown on figure 2. The washers 5 are secured to the tube 3 with a threaded connection, and are in this way rigidly connected to the tube or the longitudinal central body 3. The damping body 1 is placed between these washers 5. Two elastic elements 2 are placed between the two washers 5 and the damping body 1, such that one of the end faces of each elastic element 2 is rigidly connected to the two washers 5. The other end face of each elastic element 2 is rigidly connected to the damping body 1.

On figure 3, a damping apparatus according to the known art, build into a boring bar 9, is shown. The boring bar 9 has a cooling duct 11 in direct communication with the central tube 3, and these are aligned with the axis 12 of the boring bar.

It is also possible to use the damping apparatus according to the invention to external damping of for instance a plane object, and figure 4 shows a mounting bracket for such use. The axially extending longitudinal central body 3 is then fixed to two brackets 13 that again are rigidly secured to the body that is to be damped. The rest of the damping apparatus is of the same embodiment as the one on figure 2. In this case, the longitudinal central body does not need to be hollow.

The damping apparatus works generally in the following way:

When the construction that is to be damped, for instance the tool holder, is put into motion due to effects of external forces for instance from a cutting tool, some of this motion is transferred through the elastic elements to the mass of the damping body. Due to the geometry and the connection between the washers and the damping body, the elastic elements will experience this as shear forces. The motion (energy) that is not transferred from the tool holder through the tube and via the elastic elements to the damping body will be transformed to energy in form of heat in the elastic elements, and in some cases, the damping fluid. The heat is in this case generated by internal friction in the damping fluid and in the elastic elements, in addition to the various interfaces.

During continuous operation, a typical oscillating motion is occurring and the tool holder and the damping body will substantially move with the same frequency, but phase and acceleration will be slightly different. The difference in phase causes the necessary deformation/friction in the elastic elements and the damping fluid, which gives an energy loss as heat generation. Therefore also the acceleration of the tool holder and the damping body becomes different, and the damping force is in direct relationship to this difference.

**Patent claims:**

1. Damping apparatus for the damping of vibrations in tool holders, machine elements and work pieces in machine tools and other objects exposed to unwanted vibrations, adapted to be provided in or on the object, including a substantially cylindrical damping body (1) with a boring (6) going there through and a through the boring (6) extending longitudinal central body (3) rigidly connectable to the object that is to be damped, and the damping body (1) is connected to the longitudinal central body (3) through two elastic elements (2),  
5 characterized in that the elastic elements (2) are shaped with two substantially opposing end faces and an opening where the longitudinal central body (3) is passing;  
10 two washers (5) rigidly connected to the longitudinal central body (3) such that the damping body (1) is placed between these washers (5); and  
15 the elastic elements (2) are placed between the two washers (5) and the damping body (1) such that one of the end faces of each elastic element (2) is rigidly connected to the damping body (2), such that the elastic elements (2) are substantially exposed to shear forces during relative movement between the damping body (1) and the longitudinal central body (3).  
20
2. Damping apparatus according to claim 1,  
characterized in that the elastic elements (2) are made of an elastomer material and are secured by chemical bonding or during a vulcanization process.  
25
3. Damping apparatus for the damping of vibrations according to claim 1,  
characterized in that the elastic elements (2) are made as elastic washers or short hollow cylinders with parallel end faces.
- 30 4. Damping apparatus according to claim 1,  
characterized in that the elastic elements (2) are connected to the

damping body (1) and the washers (5) through intermediate washers (7) connected to the washers (5) with for instance adhesive bonding or mechanical locking.

- 5 5. Damping apparatus according to claim 1,  
characterized in that a thickness of the elastic elements (2) or distance  
between end faces is dimensioned to determine the natural frequency of the  
damping body (1), and that the natural frequency thereof may be adjusted by  
changing this thickness.

10

6. Damping apparatus according to claim 1,  
characterized in that the outer diameter of the longitudinal central body  
(3) is adapted to the diameter of the boring (6) with a small gap for accepting a  
damping liquid (4).

15

7. Damping apparatus according to claim 6,  
characterized in that the damping body (1) includes an opening for  
injecting the damping liquid in the gap.

20

8. Damping apparatus according to claim 1,  
characterized in that the damping body (1) is adapted to be provided  
in a for the purpose suited cavity in a boring bar (9) that is substantially axial and  
cylindrically shaped inside the boring bar (9);  
that the longitudinal central body (3) consists of a tube, extending axially, and  
25 that can lead a cooling fluid, in which tube (3) is rigidly connectable to the inner  
boring of the boring bar (9) for a cooling fluid.

FIG. 1

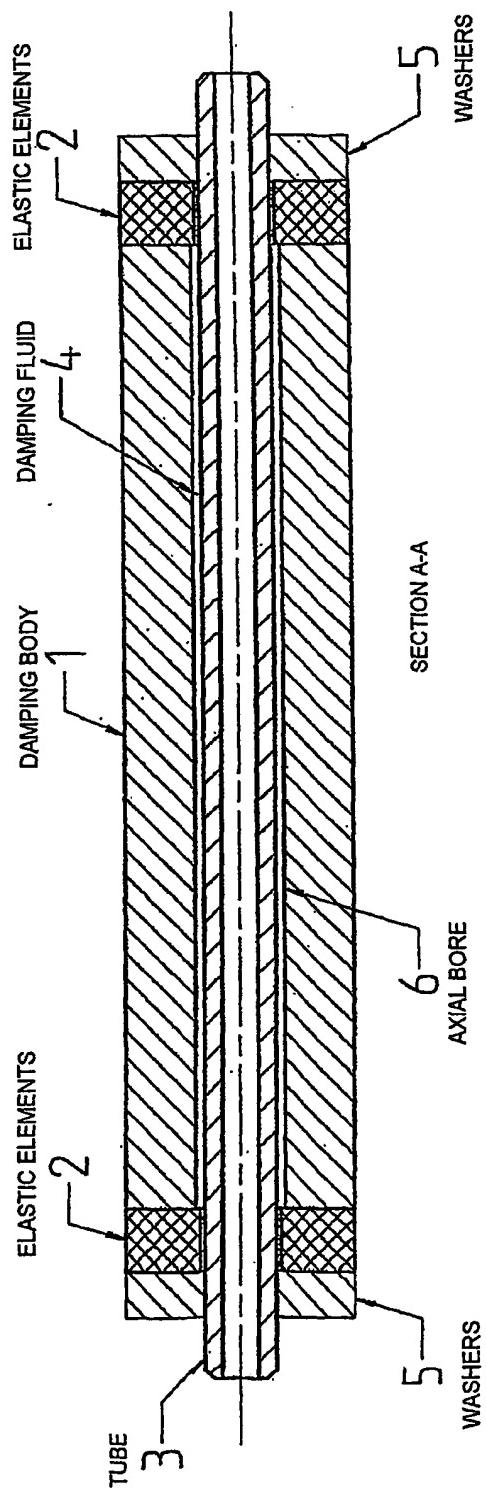
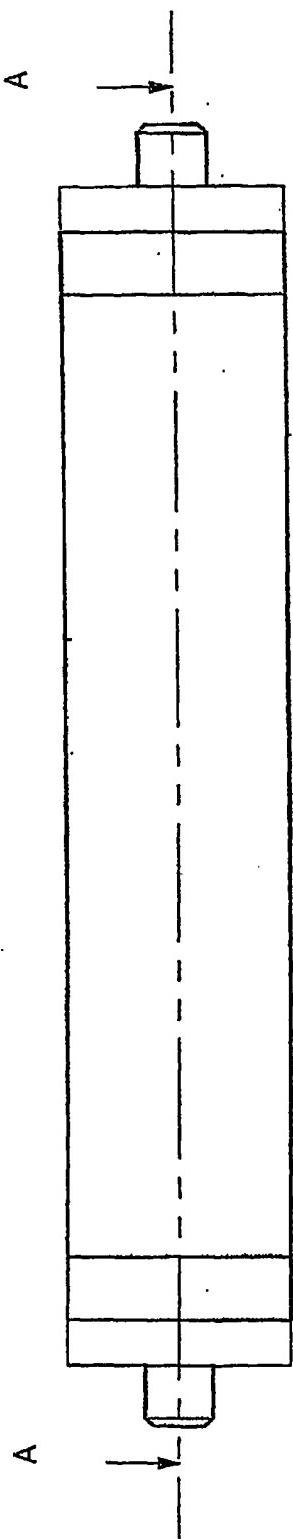


FIG. 2

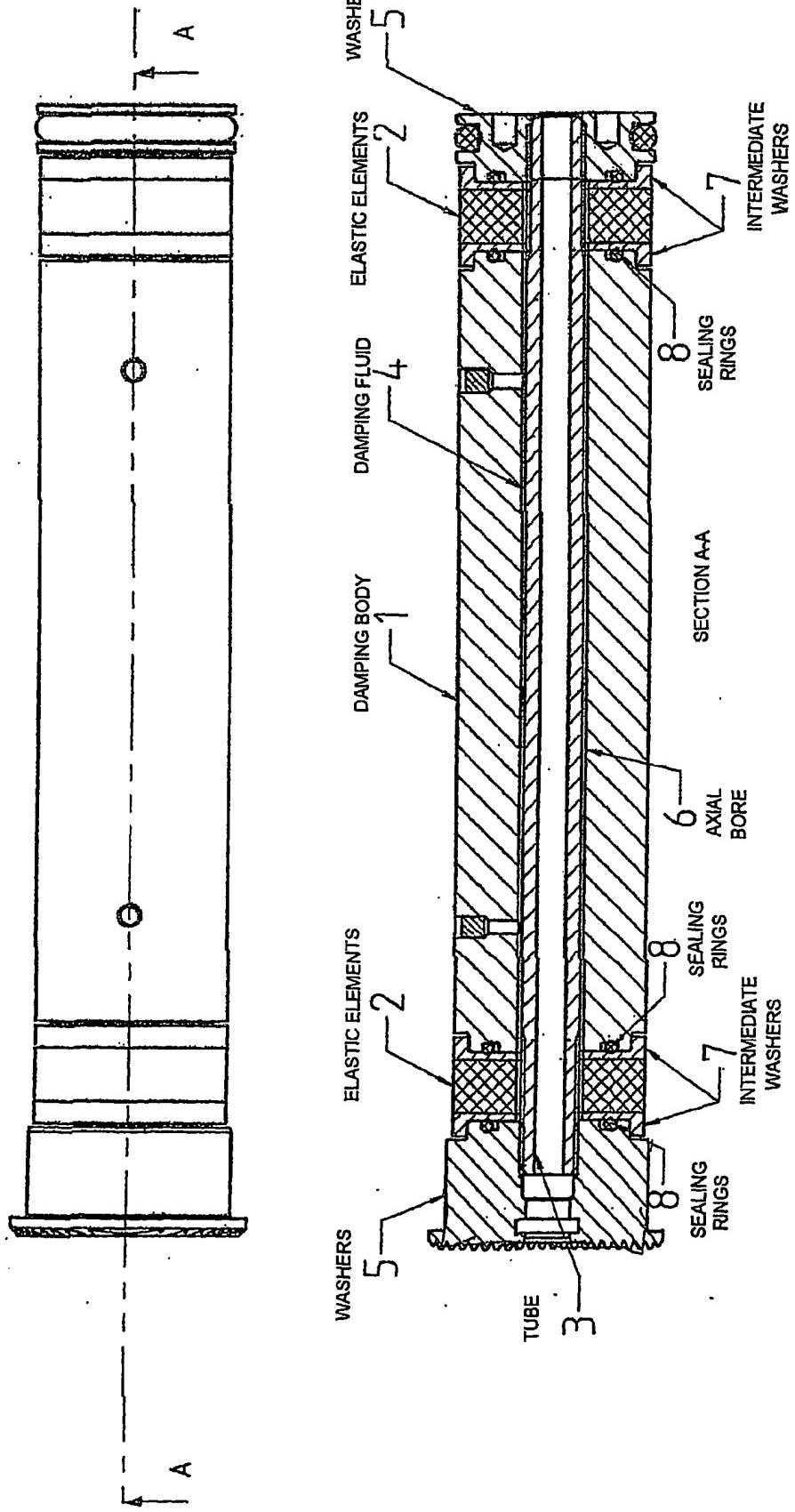
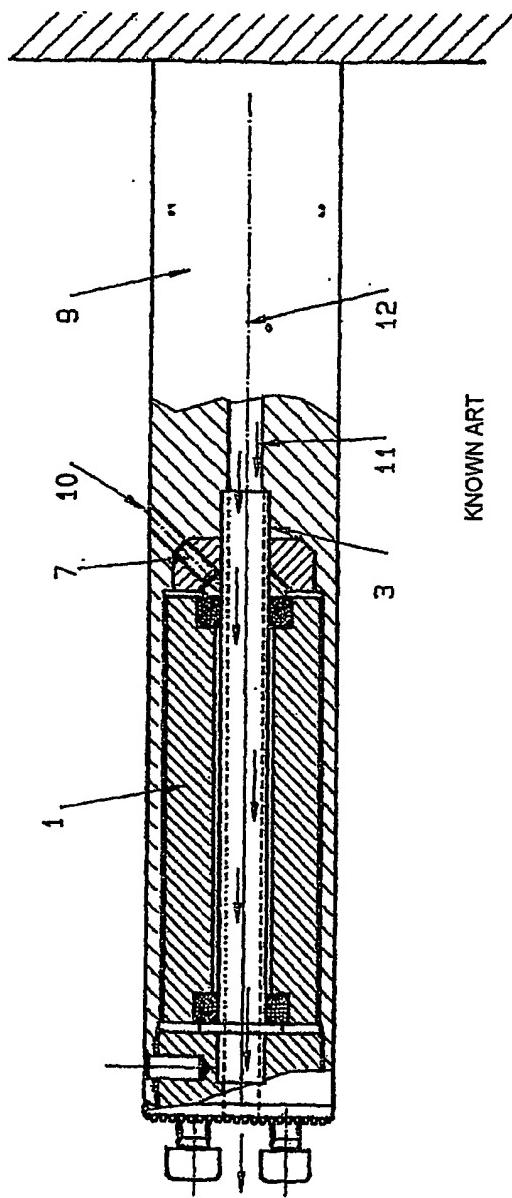
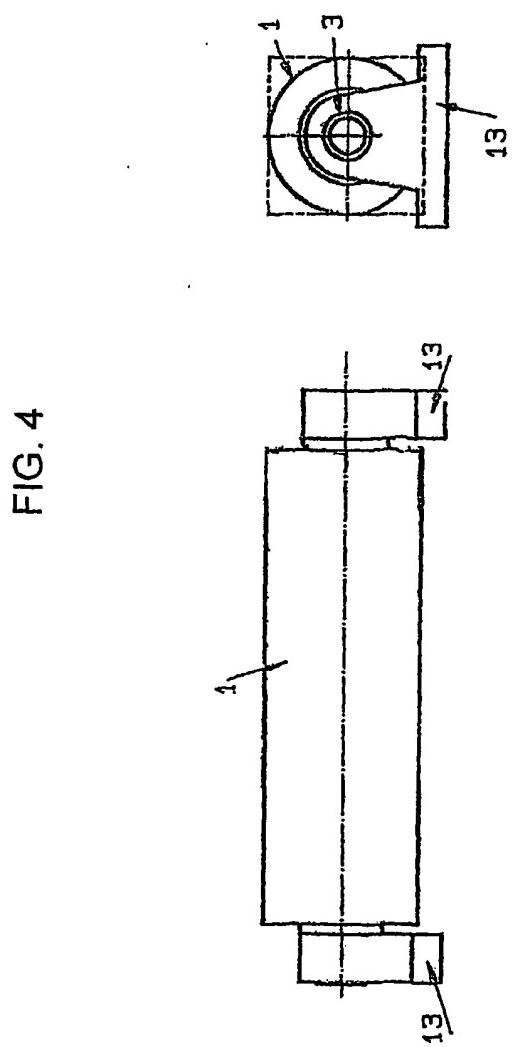


FIG. 3





(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization International Bureau



(43) International Publication Date  
13 November 2003 (13.11.2003)

PCT

(10) International Publication Number  
**WO 2003/093696 A3**

(51) International Patent Classification<sup>7</sup>:

**B23B 29/02**

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(21) International Application Number:

PCT/NO2003/000124

(22) International Filing Date: 14 April 2003 (14.04.2003)

(25) Filing Language: Norwegian

(26) Publication Language: English

(30) Priority Data:  
20022077 30 April 2002 (30.04.2002) NO

(71) Applicant (*for all designated States except US*): TEE-NESS AS [NO/NO]; P.O. Box 3532, N-7419 Trondheim (NO).

(72) Inventor; and

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(74) Agent: BRYN AARFLOT AS; P.O. Box 449 Sentrum, N-0104 Oslo (NO).

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

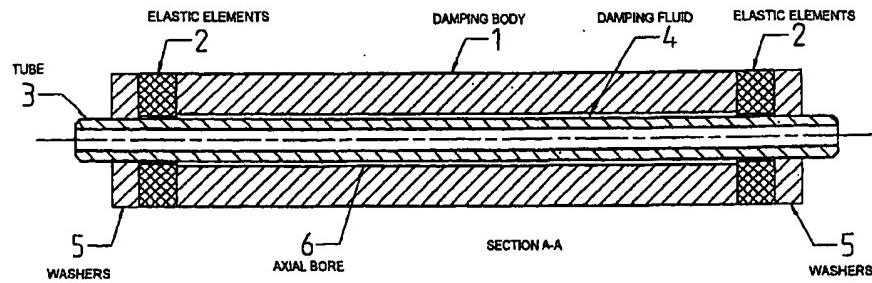
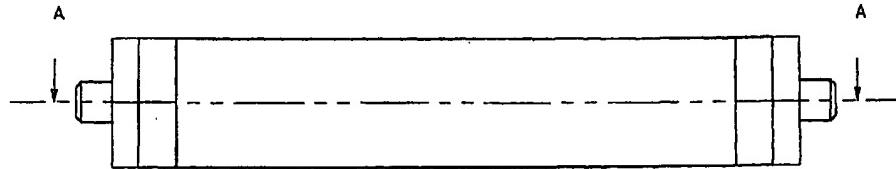
Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

(88) Date of publication of the international search report:  
8 January 2004

[Continued on next page]

(54) Title: DAMPING APPARATUS FOR THE DAMPING OF VIBRATIONS



(57) Abstract: The present invention concerns a damping apparatus for the damping of vibrations in tool holders, machine elements and work pieces in machine tools and in other objects that are exposed to unwanted vibrations. The damping apparatus is adapted to be provided in or on the object and includes a substantially cylindrically shaped damping body (1) with a boring (6) going therethrough and a through the boring extending longitudinal central body (3) that is rigidly connectable to the object that is to be damped. The damping body (1) is connected to the longitudinal central body through elastic elements (2). The connection is made such that the elastic elements (2) are substantially exposed to shear forces during damping.

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WO 2003/093696 A3



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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 03/00124

## A. CLASSIFICATION OF SUBJECT MATTER

**IPC7: B23B 29/02**

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

**IPC7: B23B, N23Q, B25D, F16F**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

**SE,DK,FI,NO classes as above**

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**EPO-INTERNAL, WPI DATA, PAJ**

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 6095922 A (FRIEDRICHSEN ET AL), 1 August 2000 (01.08.00), abstract, figure --	
A	US 3559512 A (T.C. AGGARWAL), 2 February 1971 (02.02.71), column 2, line 12 - line 15 --	
A	NO 172677 B (TEENESS AS), 18 May 1993 (18.05.93) --	

 Further documents are listed in the continuation of Box C. See patent family annex.

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- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "&" document member of the same patent family

Date of the actual completion of the international search  <b>27 October 2003</b>	Date of mailing of the international search report  <b>12 0 -10- 2003</b>
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer  <b>Annette Riedel / JA A</b> Telephone No. + 46 8 782 25 00

**INTERNATIONAL SEARCH REPORT**International application No.  
PCT/NO 03/00124**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

06/09/03

International application No.

PCT/NO 03/00124

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